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Keywords

alteration, listwaenite, great, analysis, geochemical, england, serpentinite, mineralogical, petrological, creek, bingara, belt, spring, nsw, GeoQUEST

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A petrological, mineralogical and geochemical analysis of listwaenite alteration at Spring Creek Bingara in the Great Serpentine Belt, New England, NSW

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Keywords: Listwaenite, silica-carbonate, serpentinite, Bingara, petrology, epithermal, gold.

Introduction

The Great Serpentine Belt (GSB) is a significant geological feature of northern NSW and has been studied for over a century. The silica carbonate alteration zones (listwaenites) within the GSB have been previously mapped and analysed by Paul Ashley (1997), as well as in theses by Rodgers (1986), and Breyley (1990). However, detailed mapping of the listwaenite outcrops, and investigation of the mineralogical, petrological and geochemical changes of the silica carbonate alteration zone within the serpentinites at Bingara has not been undertaken. This project focuses on listwaenite outcrops in the upper reaches of Spring Creek, a gold bearing stream near the Bingara township (UTM 0268000-0269000 E and 6687000-6690000 N), a 3km² area slightly south-east (3.5km) of the Bingara (Fig. 1), and 135km north-north-west of Tamworth. The study area lies on the northern section of the Peel Fault and is situated within the Weraera terrane (Fig. 2); which has been defined as a dismembered ophiolitic mélange.

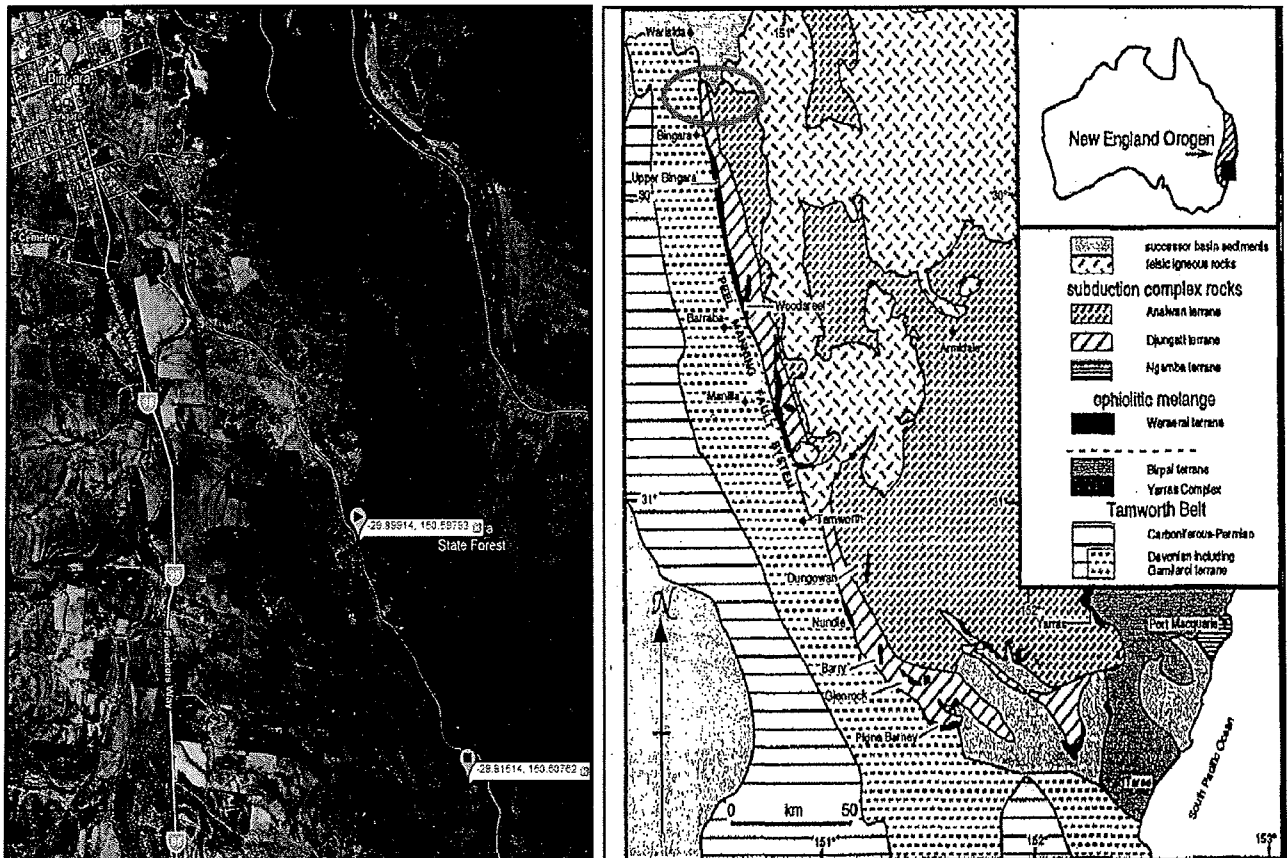


Fig. 1 Google map image of study area; red line delineates the mapping area (© 2010Google imagery).

Fig. 2 Tectonostratigraphic map from Aitchison and Ireland (1995).

The three aims of this honours thesis were to study the relationship between the serpentinite host rocks and the area of listwaenite near Bingara, to describe the changes that occur across the zone of alteration, and to identify any mineralisation that is associated with the listwaenites. Results from this thesis will provide further insight into the geochemical, mineralogical and petrological changes that occur within the serpentinites due to the listwaenite alteration fluids, and thus provide a model for their development. Listwaenites are well documented sources of gold, mercury and other economically significant minerals. The data and alteration model that result from this study will be a significant tool for future exploration within the GSB. This model could also be applied to other areas of listwaenite alteration in similar tectonic settings.

Serpentinites are produced by the hydration and exothermic chemical alteration of peridotite (ultramafic) rocks, and are predominantly composed of the serpentine minerals lizardite, antigorite, and chrysotile (O'Hanley, 1996). The type of serpentinitisation reaction that occurs is dependent on the mineral composition

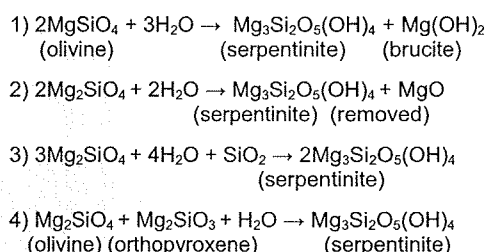


Fig. 3 Reactions involved in serpentinitization (O'Hanley, 1996; Ucurum, 1996; Buckman, 2000)

of the original peridotite (Fig. 3 below). If the reaction involves only olivine (dunite) and water the reactions 1 to 3 will occur. If olivine and orthopyroxene are present in uneven ratios (harzburgite) then reactions 1 to 3 will still occur. When the ratio of olivine to orthopyroxene is 1:1 though, reaction 4 occurs and serpentinite is produced in a single reaction (O'Hanley, 1996; Ucurum, 1996; Buckman, 2000).

The GSB serpentinites have been found to be largely schistose, steeply dipping, 40-100% serpentinitised, and to predominantly have a tectonised harzburgite precursor (Rodgers, 1986; Breyley, 1990; Aitchison, 1994, 1995; Ashley, 1997) (Fig. 5). Partly serpentinitised cumulate wehrlite, rare dunite, partly altered gabbro and minor basalt have also been identified within the GSB ophiolitic mélange (Aitchison et al, 1994; Ashley, 1997).

Listwaenites are products of hydrothermal alteration produced by CO_2 -rich fluids reacting with serpentinite. They are also known as silica-carbonate rocks and the process by which they form can also be referred to as 'carbonitization'. The chemical reaction that takes place depends on the composition of the serpentinite and the fluid type that reacts with it (Fig. 4). Listwaenites are common along dismembered ophiolite sequences

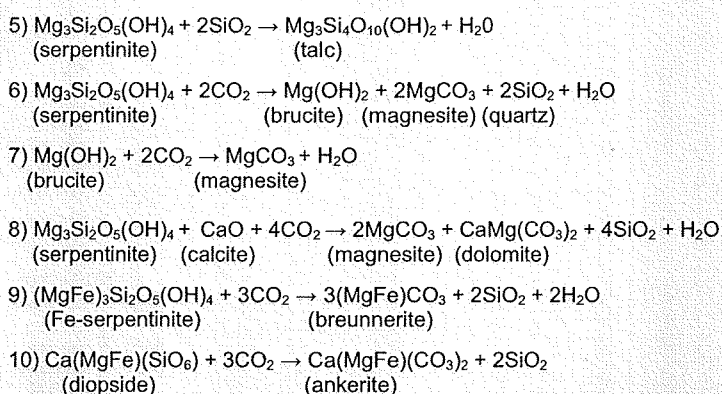


Fig. 4 Various listwaenite reactions (Ucurum, 1996).

(Ashley, 1997), fault planes or fracture zones (or a combination of all three), where the CO_2 -rich fluid can come in contact with a body of serpentinite. This is particularly true of the Peel Fault (The Great Serpentine Belt) within the New England Orogen. The listwaenite alteration zone can be a sharp contact or involve a gradual change. Where there is a gradual change carbonate porphyroblasts are present.

In the field, listwaenites have a 'gossanous boxwork' texture due to the weathering out of the

carbonates, and they have a red-brown colour due to the oxidation of the ferro-magnesium carbonates present (Buckman, 2000). A freshly broken surface usually has a slight green-orange colour as a result of the presence of the green mineral fuchsite (chromian muscovite) and ferro-magnesium carbonates (Fig. 6). Listwaenite outcrops usually form topographic highs, as they have a higher resistance to weathering than their unaltered precursors (Buckman, 2000).

The dominant mineralogy present within listwaenites is dependent on phase. Phase 1 listwaenites are carbonate dominated and are produced in the early stages of alteration. Principal minerals are dolomite, magnesite, residual serpentinite, ankerite, and rarely calcite or siderite (Tuysuz and Erler, 1993; Buckman, 2000). The alteration of serpentinite to phase 1 listwaenites involves a decrease in MgO and Au , a major



Fig. 5 An outcrop of schistose serpentinite

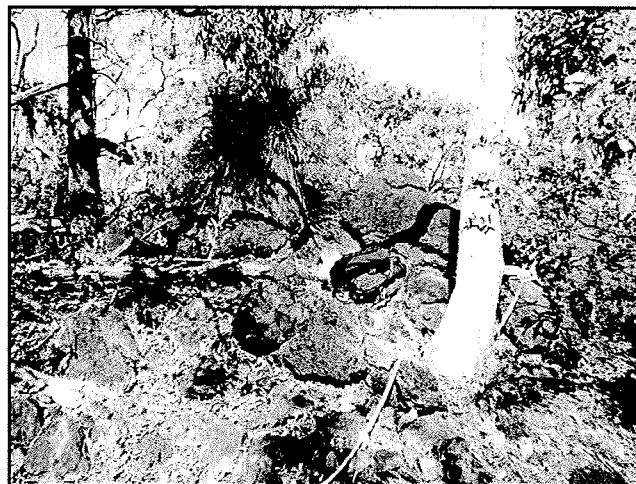


Fig. 6 An outcrop of listwaenite with typical gossanous brown colour. The grass tree growing on it is also typical of listwaenites.

increase in CO_2 , and an increase K_2O and CaO (Tuysuz and Erler, 1993). When serpentinite becomes depleted before the CO_2 , carbonate production ceases. This enables the alteration to become more silica-rich and evolve phase 2 listwaenites (Tuysuz and Erler, 1993). Phase 2 listwaenites are silica dominated and involve lower temperatures ($<100^\circ\text{C}$) and pH's (<8) (Buckman, 2000). Principal minerals are quartz, chalcedony, talc and rarely opal. Phase 2 involves a continued loss of MgO , a decrease in CO_2 , and an increase in Au (Tuysuz and Erler, 1993). Listwaenites can also contain disseminated sulfides such as pyrite, chalcopryrite, and arsenopyrite; and therefore listwaenites are economically important as they can host gold, mercury, copper, zinc and nickel (Ashley, 1997; Buckman, 2000).

In the GSB listwaenites are common along the tectonic contacts of the Weraerai Terrane, outcrops range from lensoid to tabular in form and strike parallel to the Peel Fault with steep dips (Rodgers, 1986; Ashley, 1997). Ashley (1997) revealed the hydrothermal fluid had a low salinity, was CO_2 bearing, reduced with a near neutral pH, and had a minimum homogenizing temperature of $165\text{--}200^\circ\text{C}$. Rb/Sr and K/Ar dating yielded Early Triassic ages for the listwaenite alteration ranging from $246\text{--}248 \pm 3$ Ma (Rb/Sr) and 243 ± 2 Ma (K/Ar) (Ashley, 1997). The listwaenites are predominantly carbonate rich (ferroan magnesite), and quartz is usually minor constituent occurring interstitially or as late veining (Rodgers, 1986; Breyley, 1990; Ashley, 1997).

Methods

Field mapping component was conducted over a ten day period using GPS, 1:5000 aerial photograph of the area, and a previous map drawn up by Young and Young resources. The extents of the serpentinite and listwaenite bodies were mapped, and samples were collected. This was to establish the structural and spatial relationships between each of the geological units. Three surface cross-sections were constructed across the listwaenite bodies for the purpose of identifying changes that occur over the listwaenite alteration zone. One was specifically chosen to coincide with the azimuth angle of the diamond drill hole, SCDH1 (drilled in 1984 by Freeport mining), so as to be able to establish how the alteration zone behaves vertically.



Fig. 7 Field mapping of listwaenite outcrop.

Mineralogy of the field and drill core samples was determined by thin-section, polished section, XRD and Hylogger analyses. Thin-sections also allowed textures and mineral relationships to be identified. Hylogger analysis was only conducted on the drill core samples.

Geochemistry was identified using XRF; major element, trace element and LOI analyses were performed. Assays (AAS) were performed for gold concentrations.

Results

So far the field work, the petrology, the trace XRF, and the LOI have been completed. The XRD, the reflected light petrology, the Hylogger and major XRF will be completed shortly.

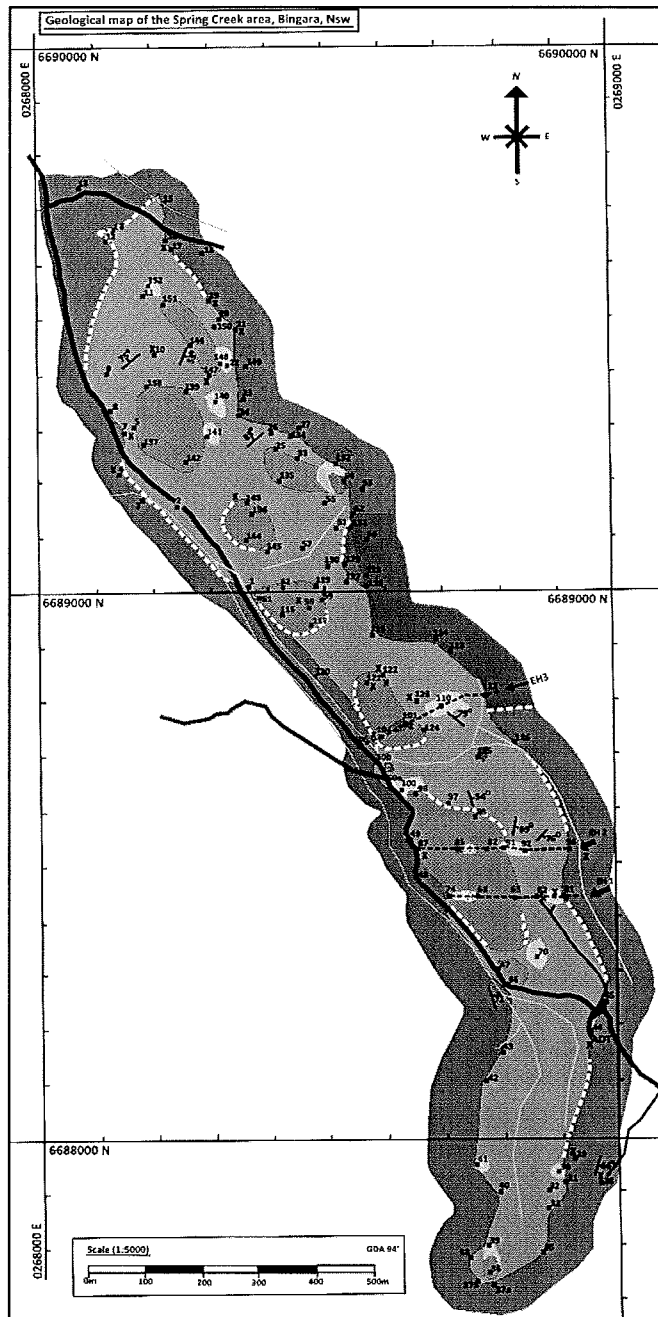


Fig. 8 Geological map of the Spring Creek study area. Red = meta-sediment, green = serpentinite, pink = listwaenite (ph 1), blue = rodingitized mafics, light blue = carbonate porphyroblast zones.

The field area was a combination of slight to steep hills, and alluvial plains. The alluvial plains made it difficult to identify the geology in some areas (the dotted lines in Fig. 7). The main rocks identified within the study area were schistose and massive serpentinite, predominantly phase 1 listwaenite with minor phase 2, radiolarian chert, and rodingitized basalt and gabbro (Fig. 7). The serpentinite has been emplaced into what appears to be a large extensional shear within the surrounding chert and rodingitized meta-basalt. The schistose serpentinite strikes NE/SW and generally dips steeply to the NE, but there were some areas that dip to the SE or NW. The listwaenite bodies range from lensoid to circular in shape and are distributed along the length of the serpentinite body. They form close to the edges of the serpentinite meta-sediment contact. Unlike previously described listwaenites do not always form topographic highs. In the study area phase 1 listwaenites were readily weathered, but where there was intense quartz veining and phase 2 listwaenites topographic highs were present. Zones of serpentinite with carbonate porphyroblasts were found throughout the study area, generally to the east of the listwaenites. Rodingitized basalts and gabbros were found as small inclusions within the meta-sediment and serpentinite areas, and as a larger unit in contact with the serpentinites' eastern margin. Smaller rodingitized mafic inclusions were identified within some of the listwaenite bodies during petrological analysis; they were difficult to separate from phase 1 listwaenites in hand specimen as they had been partially carbonitized.

The altered basalts and gabbros were comprised of plagioclase, clinopyroxene, orthopyroxene, tremolite, actinolite, chlorite, chalcedony, quartz, K-feldspar, serucite, and sometimes zoisite and adularia K-feldspar. Generally the tremolite, chalcedony and quartz occurred within veins (Fig. 9a), but tremolite is also visible within the matrix of some samples. Within a gabbroic sample the large clinopyroxenes were partially replaced by actinolite. The areas within the samples which were dominated by altered plagioclase and chlorite

(Fig. 9b) were associated with serucite, and sometimes contained zoisite. Some samples displayed cataclasite brecciation. Within the rodingitized mafics which had been partially carbonitised, carbonates formed within veins along with actinolite, adularia, quartz and possibly calcite, and had also formed small aggregates within the mafic matrix. The plagioclase within the rodingitized mafic samples found amongst the

listwaenites had been albitised. Talc was also present. The meta-sediment samples were identified as radiolarian chert, most the radiolarian was replaced by tremolite or opaques.

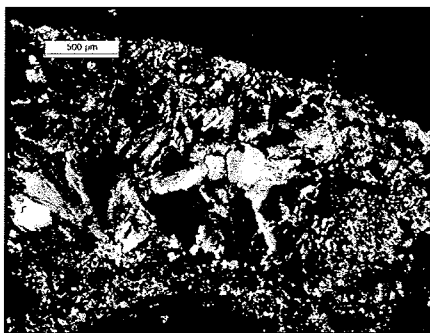


Fig. 9a Tremolite, feldspar, chalcidony vein within rod-basalt.

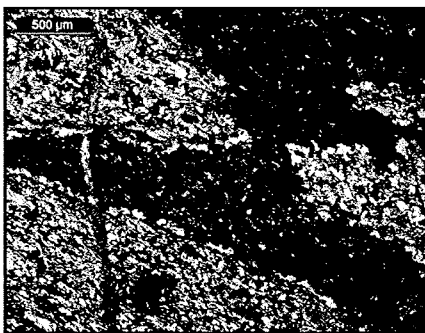


Fig. 9b Rod-basalt. Dark area is plag and chlor. Light area is trem and feldspar. Talc vein on the left.

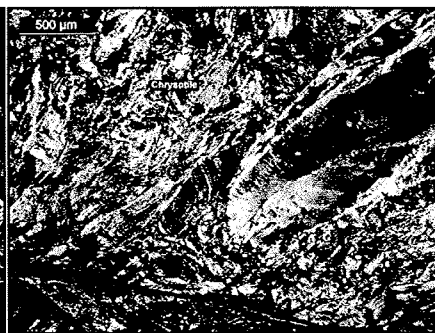


Fig. 9c Large serpentine grain within smaller 'mesh' matrix. Orange yellow areas are chrysotile.

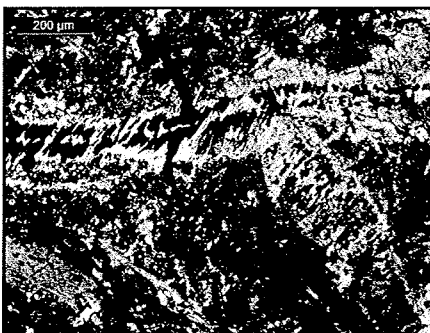


Fig. 10a Serpentine vein being replaced by magnesite.

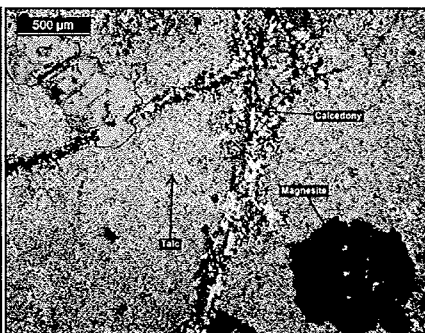


Fig. 10b Talc with carbonate porphyroblasts and chalcidony replacing it. Process of temperature decrease.

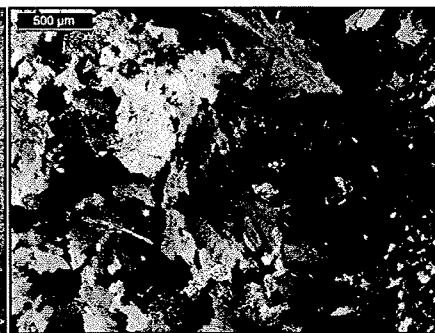


Fig. 10c Phase 1 listwaenite with magnesite and dolomite (left) and adularia (right).

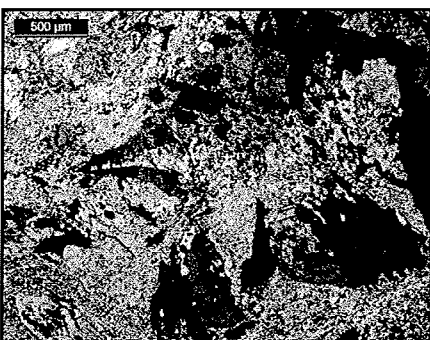


Fig. 11a Talc (high birefringence) being replaced by carbonates (lower birefringence).

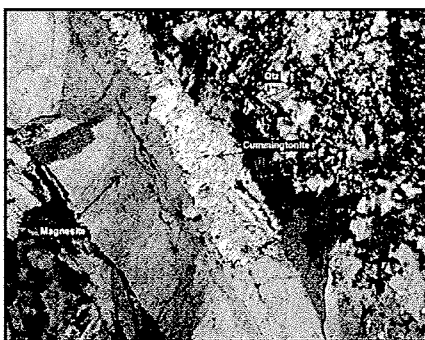


Fig. 11b Phase 1 listwaenite, with carbonate vein. Quartz in the top right corner. The cummingtonite is in the middle in the vein.

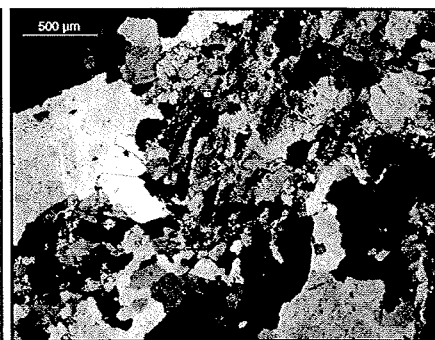


Fig. 11c Phase 2 listwaenite; quartz veins consuming the remaining carbonates.

The serpentinites were totally serpentinitised, partially serpentinitised, or serpentinitised with carbonate veining and porphyroblasts (Fig. 9c and 10a). The totally serpentinitised samples were composed of the typical mesh texture surrounding larger serpentine grains (Fig. 9c). In partially serpentinitised samples large clinopyroxenes were not yet altered. XRD has identified antigorite as the main serpentine mineral in the samples analysed so far. Chrysotile veins occurred in most samples, but featured most prominently in sheared samples. In some places the chrysotile veins were being replaced by amphibole. Magnetite was disseminated throughout the serpentine grains, and also defined veins, cleavages, and grain boundaries. Within partially carbonitised serpentinites the carbonate porphyroblasts replace un-serpentinitised pyroxenes. Carbonates also replace serpentine veins. In these samples magnetite was starting to 'dissolve' (Fig. 10a). There were also numerous samples dominated by talc, particularly within the drill core. These samples also contained carbonate porphyroblasts (Fig. 10b)

The listwaenites are predominantly phase 1; XRD has identified magnesite as the major carbonate present. Dolomite, ankerite, and possibly calcite also occur within the listwaenites (Fig. 10c). Most samples have some quartz or chalcedony. Talc is also replaced by carbonates within some samples (Fig. 11a). Occasionally cummingtonite forms as a reaction between the carbonates and silica minerals (Fig. 11b). Acicular actinolite was also observed. As the transition to phase 2 listwaenite progresses, quartz and chalcedony become more abundant. Quartz forms individual grains, eventually large veins, and then consume the carbonates (Fig. 11c). Chalcedony replaces talc along small fractures (Fig. 10b).

The trace XRF results revealed the rodingitized basalts contained the highest sulfur values, but low chromite and nickel compared to the serpentinites and listwaenites. The serpentinites also have elevated sulfur levels, high chromite and nickel levels and a slight peak in strontium. The listwaenites have high peaks in chromite and nickel; but not as high as the serpentinites. They also display peaks in arsenic and strontium. LOI analysis established that phase 1 listwaenite (27-36%), and the talc dominated samples had the highest levels (25-35%). Serpentine samples with some carbonates were high as well (22-28%). Phase 2 listwaenites LOI levels were slightly less (23%) than the later and the serpentinite samples were all around 12-14%. Rodingitized mafics and sediment had the lowest levels (4-6%) except one which was partially carbonitised (14%).

Discussion

The study area is dominated by sheared serpentinite striking predominantly NE/SW, and steeply dipping to the NE. The other lithologies identified were Listwaenite (predominantly phase 1), radiolarian chert, and rodingitized mafics. The rodingitization is closely related to the serpentinitisation, and both have been affected by the listwaenitisation fluids. Some serpentinite samples are talc dominated and so far the main serpentine mineral has been identified as antigorite; both of these indicate that serpentinitisation reached high temperatures, at least 600°C. Serpentine occurs at 430 (1Kbar)-580°C (30kbar), Antigorite forms at ~100°C higher (Deer et al, 1992). Talc can form at around 480°C (20kbar), temperature increases sharply when pressure decreases (Deer et al, 1992). Another indication of high temperatures is the presence of amphibole replacing the chrysotile veining in some samples. The presence of chrysotile within most serpentine samples is indicative of an active environment. Magnesite has been identified as the main carbonate within the listwaenites, with dolomite and ankerite also present. In some samples calcite is possibly present. Carbonitisation starts within the serpentinites by replacing un-serpentinised pyroxenes or serpentine veins. Eventually phase 1 listwaenites form. Phase 2 listwaenites start forming as individual quartz grains which continue to form veins and eventually consume the phase 1 listwaenite. During listwaenitisation chromite and nickel levels decrease, but arsenic levels increase.

Conclusion

Based on the results so far iron rich serpentinite containing diopside (as ankerite is present within listwaenites) was emplaced into a large extensional shear; surrounding sediment was metamorphosed and mafics were rodingitized. During emplacement, blocks of meta-sediment and rodingitized mafics were ripped off into the serpentinite mélange. CO₂, CaO, and As rich listwaenitising fluids (as dolomite was produced, and arsenic became elevated) intrude from points along faults or fractures which have developed within the serpentinite mélange. The listwaenitising fluid seeps into surrounding rocks; carbonates initially replace serpentine veins, and form porphyroblasts within areas with un-serpentinised pyroxenes. With continued listwaenitisation, magnesite dominated phase 1 listwaenite forms. Rodingitized mafics become albitised and carbonates start forming within veins present in the mafics. When serpentinite has been fully reacted phase 2 listwaenites start forming; quartz veining begins and eventually consumes the carbonates. Quartz also replaces the carbonates, which were present within veins in the rodingitized mafics.

A more detailed and definitive model will be concluded once the XRD, XRF majors, assays, reflected light analysis and Hylogger data has been received and interpreted.

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